Chapter 12

Subclavian artery transposition and bypass techniques for use with endoluminal repair of acute and chronic thoracic aortic pathology

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Significant proportions of patients with both acute and chronic thoracic aortic pathology are found to have disease adjacent to the origin of the great vessels. Although open surgical repair remains the best treatment option for some, management often requires hypothermic circulatory arrest to safely complete the proximal anastomosis. When patients are considered for endoluminal therapy, several different treatment paradigms have been developed for managing proximal thoracic aortic pathology.[1,2] When pathology abuts the left subclavian artery, some advocate the extra-anatomic rerouting of cerebrovascular and upper extremity blood flow with subclavian-carotid transposition or bypass.[3-7] Others advocate simply ignoring the left subclavian artery, and they deploy the covered or the bare-wire portions of the stent-graft device over the origin of the subclavian artery.[8-15] Branched endografts are currently being developed. Techniques to fenestrate the endograft material and deploy stents through the device have also been used.[16-18] There is clearly no consensus on how best to handle the great vessels in patients with proximal thoracic aortic disease. Most do agree that the status of the vertebral circulation is an important factor in choosing a treatment path.

TECHNIQUE

The subclavian artery may be transposed to or bypassed from the adjacent carotid artery. Not only is preservation of the vertebral artery critical, but it is equally important to mobilize and preserve the valuable internal mammary artery when performing a subclavian transposition. Arterial transpositions are completed through a short, transverse cervical incision above the clavicle. For a transposition, the surgical dissection is performed between the two heads of the sternocleidomastoid muscle. After the omohyoid muscle is divided, the jugular vein and the vagus nerve are reflected laterally, and the common carotid is dissected out circumferentially and reflected medially. On the left side, the thoracic duct is identified, ligated, and divided. Multiple additional cervical lymphatic channels must also be tied. After the vertebral vein is divided, the subclavian artery and its proximal branches are carefully dissected from surrounding tissues and must be controlled. The subclavian artery as it passes from the thoracic outlet is particularly thin walled, with a consistency much like the pulmonary artery. Care must be taken when manipulating this vessel. Caution should also be exercised when isolating and controlling the vertebral artery, because it takes origin from an awkward position on the posterior aspect of the subclavian. Once heparin has been administered, the subclavian is transected over a right-angled clamp, as far proximal as possible, behind the clavicle. It is important to secure the proximal stump immediately after the artery has been divided; if control of the transected stump is lost in the chest or mediastinum, the consequences clearly can be devastating. After the carotid is rotated a quarter turn counterclockwise to expose its posterior aspect, a punch arteriotomy is created on this donor vessel, and the end-to-side subclavian-to-carotid anastomosis is completed without tension by using fine monofilament suture (Fig 1).

Occasionally, it is not feasible to perform a straightforward arterial transposition, so a bypass conduit becomes necessary. Arterial transposition is not possible when the vertebral artery takes off early from the subclavian artery. Patients with a functioning coronary revascularization using an internal mammary artery should also undergo a bypass rather than a transposition to preserve myocardial perfusion during the procedure by means of sequential clamping distal to the internal mammary artery. Bypasses are performed most expediently through dissection just lateral to the clavicular head of the sternocleidomastoid muscle. The jugular vein is reflected medially to expose the common carotid. The subclavian artery is identified more distally than during transposition by dividing the anterior scalene muscle. The bypass is completed into the retroscalene portion of the subclavian artery, usually with a prosthetic conduit rather than a vein, by performing sequential clamping and serial anastomoses.

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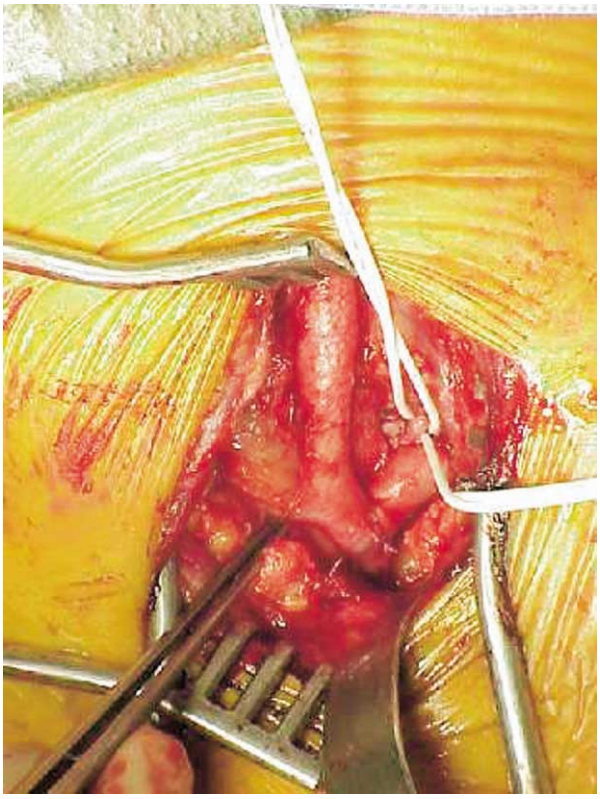

Fig 1. Completed subclavian-to-carotid transposition.

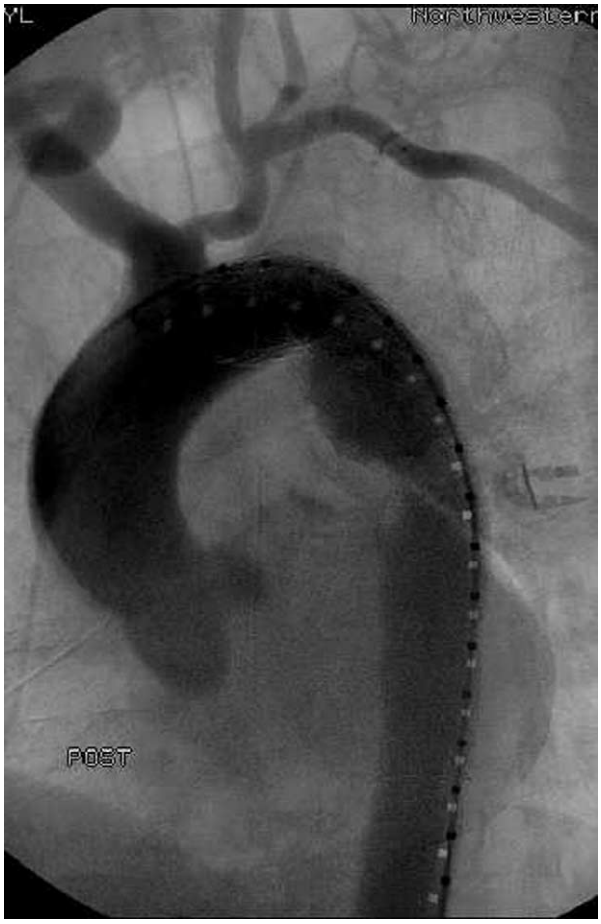

Fig 2. Endograft deployed to the origin of the bovine innominate. Note the patent transposition and dominant vertebral artery.

If more extensive arch coverage with a thoracic endograft is necessary and an extra-anatomic approach is considered, the only source vessel will be found on the opposite side of the neck. If this extra-anatomic approach is used, the midline should be crossed by using a retropharyngeal rather than a presternal or pretracheal path. The retropharyngeal route is shorter and more direct. Furthermore, pretracheal or presternal routing of a bypass graft can result in erosion of the overlying skin and will be found obtrusive if the patient ever requires a sternotomy or a tracheotomy. Long subclavian-subclavian, axillary-axillary, and femoro-axillary bypasses should also be avoided unless there is no other alternative.

Complete debranching of the aortic arch is performed through a median sternotomy. A prosthetic graft, used to reroute the extra-anatomic circulation, usually takes origin from the ascending aorta. Before heparin is administered, a side-biting clamp is applied, and the proximal anastomosis is performed end to side to a soft spot on the anterolateral aspect of the aorta distal to the aortic valve. Side branches are attached as needed to reperfuse all the great vessels.

LOCAL EXPERIENCE

The proximal extent of the aortic pathology was adjacent to the great vessels in 28 (40%) of the 70 patients treated at Northwestern Memorial Hospital. The left subclavian artery was managed by transposition into the left common carotid before the endograft deployment in 19 cases (Fig 2). This included two patients with aberrant right subclavian vessels, who had both the right and left subclavian vessels transposed at separate settings before surgery. One patient with a functioning left internal mammary coronary bypass had a prosthetic carotid-to-subclavian bypass immediately before repair of a leaking thoracic aneurysm. Another had a bypass to the subclavian artery from a reconstructed aortic arch. The arch reconstruction and subclavian bypass were performed under hypothermic circulatory arrest, and to treat descending aortic pathology, an endograft was then deployed that covered the subclavian origin. Finally, one patient required subclavian artery-to-common carotid artery transposition after later developing left upper extremity and posterior circulation symptoms following thoracic endograft placement. The remaining six patients had a nontransposed subclavian origin covered by the proximal end of the covered portion of the stent graft.

Five complications occurred in the six patients who had the subclavian origin covered without revascularization. Four of them experienced strokes. Three of these had magnetic resonance imaging–confirmed posterior circula-

Literature summary

Study	*Proximal aortic cases*	*Subclavian covered*	*Subclavian transposed*	*Outcome*
Mitchell[23]	13	2	11	1 neuro
Grabenwoger[7]	9	0	9	No complications
Moore[14]	1	0	1	No complications
Hausegger[9]	6	4	2	No complications
Cambria[12]	6	0	6	No complications
Criado[1]	13	5	8	1 lymphatic (transposition)
Criado[2]	9	2	7	No complications
Gorich[8]	22	21	1	4 endoleaks, 4 neuro, 2 UE, 1 spinal
Heijmen[6]	5	0	5	No complications
Burks[15]	3	1	2	No complications
Tiesenhausen[10]	10	8	2	2 endoleaks, 3 neuro
Lambrechts[13]	7	6	1	No complications
Hutton[24]	1	1	0	1 neuro
Hansen[25]	4	4	0	No complications
Leurs[26]	79	42	37	1 neuro
Northwestern	30	8	22	4 neuro, 1 UE, 2 VC palsy (transposition)
Total	218	104	114	Complications: 23% vs 3%

Nuero, Nuerological; *UE,* upper extremity; *VC,* vocal cord.

tion strokes. In two cases, the infarcts were confined to the distribution of the posterior circulation, ipsilateral to the covered subclavian artery. Upon further review of available imaging, in both cases the contralateral vertebral was hypoplastic or absent. One patient, mentioned previously, developed symptoms of subclavian-vertebral steal, including arm fatigue/pain and syncope, shortly after endograft placement and left subclavian coverage. This patient required subclavian revascularization via subclavian-to-carotid transposition 7 months after the endograft procedure for treatment of persistent posterior circulation symptoms.

Among the 22 patients who underwent subclavian reconstruction before or after endograft placement, 2 complications were directly related to this procedure. Two patients experienced left-sided vocal cord palsy, presumably related to traction on the vagus or the recurrent nerve. The paralyzed vocal cords were confirmed 1 month after the procedure by indirect laryngoscopy. Both patients had clinical resolution of their symptoms 3 months later after undergoing cord injection with silicone. Another patient from this group experienced delayed spinal cord ischemia and bilateral lower extremity paresis after endograft placement. There were no strokes or procedure-related deaths in this group. All subclavian-to-carotid artery transpositions have remained patent at a mean follow-up of 18 months (range, 1-51 months), and there has been no late morbidity related to the transposition procedure.

DISCUSSION

Although various types of pathology may abut the left subclavian artery, some disease processes—namely, traumatic transection and dissection—generally occur within close proximity to the origin of the great vessels. This occurrence underscores the importance of being able to position endoluminal devices high in the descending thoracic aorta, even with extension into the aortic arch, if we are to treat these lesions by endovascular means. In our experience, 40% of patients who underwent endovascular repair of acute or chronic thoracic aortic pathology had lesions that were adjacent to or involved the origin of the great vessels.

Previously published series have addressed the topic of proximal thoracic aortic pathology, but no consensus on how best to treat these patients has arisen. The initial Gore Thoracic Excluder endograft trial design required pretreatment subclavian relocation or bypass for proximal aneurysms to minimize ischemic complications or continued sac perfusion. Other device trials have left this important decision up to the discretion of the operator.

Some groups have sought to lengthen the proximal landing zones via carotid-to-carotid and carotid-to-subclavian artery bypass.[3-7] Although these bypass procedures may address the issue of lengthening the proximal neck to ensure an adequate seal length, they generate the potential for type II endoleak. Furthermore, bypass allows for continued perfusion of the sac in the setting of aneurysmal disease or of the false lumen in the case of dissection.

Some groups have demonstrated success by using techniques designed to maintain normal great vessel perfusion with scallop-edged or bare metal–ended stent grafts.[14,15,18,19] Alternatively, some have used stent-graft fenestration and retrograde stent deployment through the device and into the arch branch. Branched endovascular prostheses are presently being developed, but widespread acceptance is likely years away.[16,17] Large series and long-term follow-up are lacking.

Perhaps the added complexity of great vessel management is unnecessary and coverage of the great vessel origins, at least the left subclavian, can be routinely performed with impunity. Indeed, some groups have suggested that coverage of the left subclavian artery is well tolerated and

that extra-anatomic bypass or transposition should be reserved for patients who subsequently develop symptoms that necessitate intervention.[8-15] A recent literature summary (Table) would suggest that subclavian coverage may not be so benign. Complications arising directly from subclavian coverage occurred in 23% of patients, whereas similar complications did not occur in the patients who had subclavian perfusion maintained.[20] Our cohort of patients had similar complications after subclavian coverage. In fact, four of six patients who underwent coverage of the subclavian origin in our series developed strokes in the immediate postoperative period. Although we cannot state with certainty that these would have been prevented by antecedent transposition and one could certainly argue that proximal disease is simply a marker for increased stroke risk overall, the findings of isolated posterior circulation events in two of our patients with absent or hypoplastic contralateral vertebral arteries certainly would suggest that ipsilateral vertebral perfusion remains critical. The fifth patient who required late subclavian revascularization for persistent posterior circulation symptoms also adds credence to this viewpoint.

Although perhaps not necessary in every case, transposition of the subclavian to the carotid artery has many inherent advantages over great vessel coverage. The advantages of maintaining adequate perfusion to the left upper extremity and to the ipsilateral vertebral artery via the left subclavian artery are obvious. Additionally, spinal cord perfusion is optimized by preserving important collateral perfusion via the vertebral artery and its anterior spinal branch. As mentioned previously, the potential for a type II endoleak or continued perfusion of a dissected false lumen from retrograde subclavian blood flow is eliminated after a transposition procedure. The risks associated with subclavian transposition in experienced hands are few.[21,22] The procedure was well tolerated in the 22 patients in this series who underwent subclavian-to-carotid artery transposition. The two patients who developed left-sided vocal cord palsies had resolution of symptoms within a matter of months without residual morbidity. In addition to the present series, which demonstrated 100% patency rates at 18 months of follow-up, the safety, efficacy, and durability of subclavian-to-carotid transposition are well known.[21,22]

Despite the relative ease and low morbidity of bypass or transposition, perhaps we should be selective. Besides risk to the recurrent and vagus nerves, other complications, including bleeding, thoracic duct leak, lymphocele, and Horner syndrome, can also follow transposition. Although many alternative paradigms exist, we choose to perform transposition procedures when situations necessitate the rerouting of the arch vessels for the aforementioned reasons. We would argue that, in instances when thoracic aortic pathology arises within 15 mm of the origin of the most distal great vessel, prophylactic subclavian-to-carotid artery transposition or bypass is warranted when the dominant vertebral artery arises ipsilaterally. In elective circumstances and when time permits, we choose to perform preoperative imaging of the extracranial cerebrovasculature by using magnetic resonance angiography to fully assess the status of the vertebrobasilar system before deciding to transpose or cover. In situations when urgent or emergent endovascular reconstruction is necessary (as in traumatic aortic transection), we make every effort to image these same vessels, at least proximally, with catheter-based angiography before deploying the device. When patients present with extensive descending thoracic pathology and coverage of multiple intercostal vessels is necessary, a transposition procedure to maintain optimal spinal cord perfusion may be useful. Patients with very proximal aneurysms and those with descending thoracic dissections with a prohibitive risk for open repair require definitive management of the great vessels to avoid retrograde flow into the aneurysm sac or into the dissected false lumen. Finally, it is important to remember that patients with previous coronary revascularization using the left internal mammary as a bypass conduit require carotid-to-subclavian bypass if the origin of the subclavian is to be sacrificed.

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